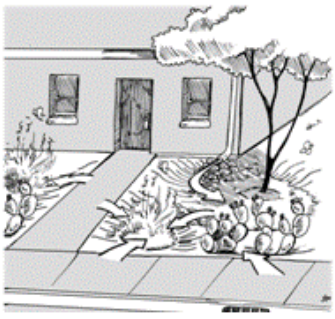
Residential Rainwater Harvesting

A Guide to Water-Wise Planning and Design

Principles of Rainwater Harvesting

- **Know how water moves on your property.**
- **Keep as much water on your property as you can.**
- **Protect your soil.**



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PREFACE

1.1. ACKNOWLEDGEMENTS

While this Guide was prepared by Staff of the City of Flagstaff, Stormwater Management Section, this document was largely adapted from the publication *Stormwater as a Resource, How to harvest and protect a dryland treasure,* produced by the City of Santa Fe in collaboration with the College of Santa Fe. It was funded in part by a Clean Water Act Section 319 grant administered by the New Mexico Environment Department and U.S. Environmental Protection Agency Region 6. Unless otherwise noted, the illustrations in this Guide were from *Stormwater as a Resource*, done by Bob Hill, City of Santa Fe Graphics Division.

In addition, two information sheets produced by the University of Arizona Cochise County Cooperative Extension Water Wise Program were used in part for the development of this Guide. These publications are *Rainwater Collection - Basic Components of a Rainwater Storage System* and *Rainwater Collection - Passive Water Harvesting.* Thanks to Ms. Cado Daily, Program Coordinator Senior for the Water Wise Program for her assistance in providing these materials.

The City of Flagstaff, Stormwater Management Section would also like to acknowledge the assistance provided by the members of the Sustainability and Water Commissions. We are grateful for the Commission's time commitment and all of the comments and suggestions provided by the Commissions in preparation of this document.

1.2. GENERAL INTENT

The intent of this Guide is to provide information on harvesting rainwater utilizing landscape based techniques. This Guide was primarily developed for use by individual homeowners to assist them in meeting the requirements of City of Flagstaff Ordinance 2012-03. However, the techniques presented in this Guide are also applicable to anyone who wishes to redesign an existing landscape to take advantage of the runoff created during a rain storm, either residential or commercial/institutional/industrial.

1.3. DISCLAIMER

The information given herein is supplied with the understanding that no discrimination is intended and no endorsement by the City of Flagstaff is implied. Any products, services, or organizations that are mentioned, shown, or indirectly implied in this publication do not imply endorsement by the City of Flagstaff, and are merely used to illustrate the availability of potential products and sources of materials that meet the characteristics for the water harvesting methods recommended herein. It is encouraged to always consider the use of other products or brands that will provide equivalent or better level of performance or service.

As with any release of publications and details, it is likely that some nonconformities, defects, and errors associated with this Guide will be discovered. The City of Flagstaff, Stormwater Section welcomes and encourages user feedback in helping to identify them so that improvements can be made to future releases of the Guide and other products.

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1. RESIDENTIAL RAINWATER HARVESTING REQUIREMENT

The City of Flagstaff Stormwater Design Manual, Chapter 9, *Low Impact Development Requirements for Infiltration and Reuse of Stormwater and Rainwater Harvesting* states that new single family residential dwellings shall utilize passive rainwater harvesting techniques. At a minimum, this means roof downspouts, if utilized, shall be directed to landscape and/or natural areas and no direct connection of downspouts to the street, right-of-way or any property line shall be allowed. For driveways that slope to the street, right-of-way or property line, efforts shall be made, insofar as practical, to direct driveway flows into natural or landscape areas. This publication will provide the tools necessary to meet and exceed the rainwater harvesting requirement.

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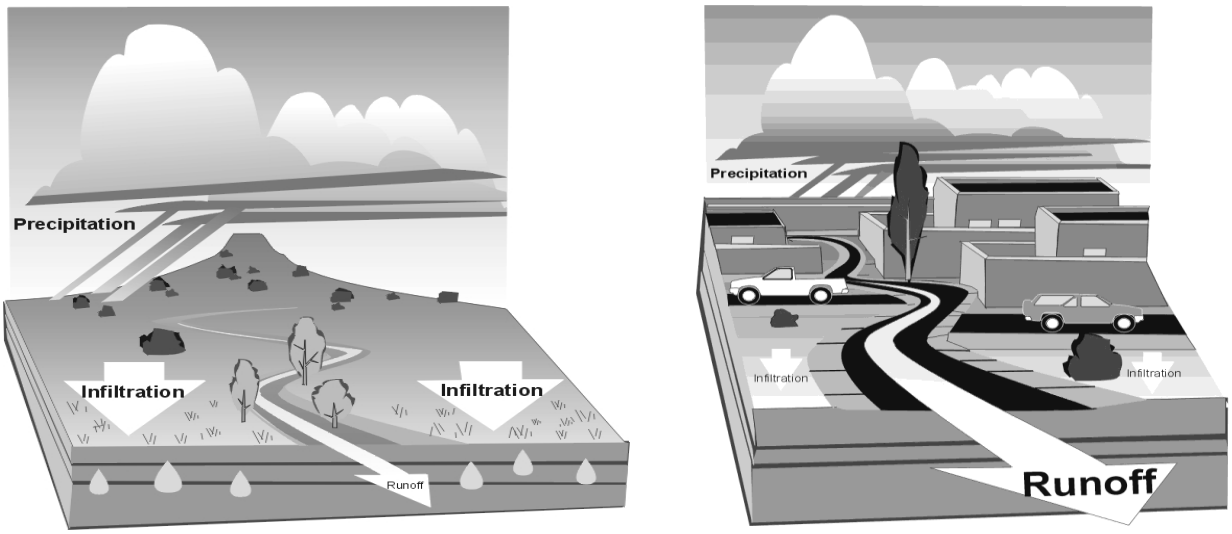
2. INTRODUCTION

Passive water harvesting is the practice of slowing water down and encouraging it to soak into the ground. By building simple structures, stormwater can be used beneficially, encouraging plant growth in landscapes and natural areas, healing erosion cuts, and can even replace the need to irrigate with potable water. The key is capturing rain and snow that falls on your property instead of letting it run off uselessly to cause erosion and flooding. Here's why we need to do it:



In an undisturbed arid Southwest environment the rain and snowmelt soaks into the ground very close to the location it falls. This localized infiltration:

- *Supports plant life*
- *Maximizes ground water recharge*
- *Minimizes flooding and erosion.*

Only the heaviest thunderstorms produce surface runoff - everything else soaks into the ground.

Plants do use water, but ground cover plants, especially native grass, let more water soak in than they use. As a result, ground water recharge is generally greater with a vegetated ground surface.

Things are very different in an urban setting:

- *Much of the land surface - roofs, driveways, roads, and so on - is impervious to water.*
- *Water runs off the impervious surfaces almost instantly, so gullies and arroyos fill up quicker and have to carry much more water.*
- *The extra water in the arroyos moves faster, increasing erosion and property damage. Eroded soil fills reservoirs and causes water pollution.*
- *The additional runoff makes flooding worse.*
- *All the additional runoff is water that can no longer soak in to help recharge ground water.*

1.4. STORMWATER IS A VALUABLE RESOURCE

Urban areas don't have to lose all their runoff water! This handbook is a guide to many different ways to keep that wonderful water around, let it soak into the ground and avoid erosion and flooding.

Section I suggests how to think about working with your land to take advantage of its natural features and runoff patterns.

Section II describes how to catch and use water in many different situations.

Section III deals with how to prevent and repair erosion problems, including how to keep soil on-site and prevent erosion during construction.

The beautiful landscape in this photo is supported by water "harvested", or captured before it could run off. It's a dramatic illustration of how to put stormwater to very attractive use.

We have gotten used to thinking of rain and snow as just a nuisance. But did you realize that all the water we'll ever have comes from precipitation? Even the deepest ground water originally fell as rain or snow – it's just stored underground. The only way we can ever replace any of the water we pump and use is to allow precipitation to soak back into the ground and recharge the ground water. However, much of Flagstaff is paved or roofed, a lot of water is running off uselessly and very little is soaking in to recharge our ground water.

1.4.1. It's a win-win situation. As individuals, we can have:

- *Thriving landscapes and gardens using less water*
- *Lower water bills*
- *Erosion damage prevented or repaired*
- *A new connection to our beautiful landscape*

1.4.2. As a community, we get a lot of important benefits too:

- *Increased water supplies, from more infiltration as well as less irrigation demand*
- *Protected and improved water quality*
- *Reduced flooding*
- *Less tax money spent on repairing erosion damage and treating water pollution*
- *A healthier urban ecosystem.*

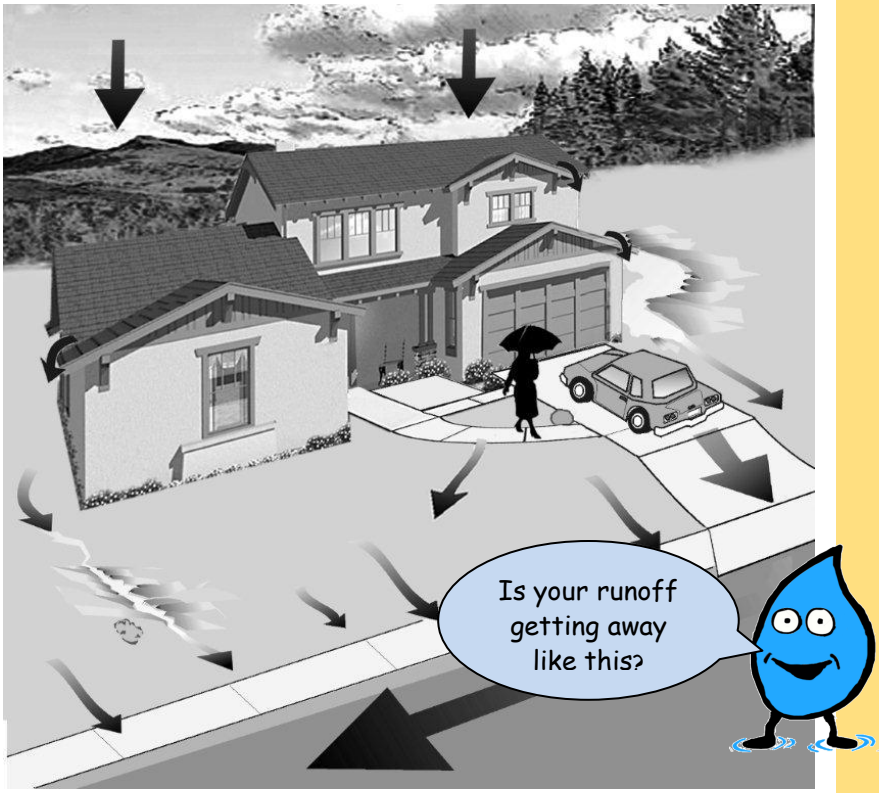
3. SITE PLANNING AND DESIGN: THINK LIKE A RAINDROP

These three basic principles are the keys to water-wise planning and design:

1. **Know how water moves on your property.**
2. **Keep as much water on your property as you can.**
3. **Protect your soil.**

1.5. KNOW HOW WATER MOVES ON YOUR PROPERTY

The best way to start conserving and making better use of precipitation is to follow the raindrops - notice where water goes on your property. Take advantage of opportunities to contain it, slow it down, spread the water out, and soak it in. Don't let it get away!



After (or better yet, during!) the next rainstorm, take a good look at your yard.

- How does water flow across the land? Look for pine needles or leaves moved by water as it flows over the land.
- Where does it collect or puddle?
- Where does it soak into the ground?
- When water flows off the roof, driveway, walkways, or other hard surfaces, where does it go?
- Are there rills, gullies, or other signs of erosion?
- Does water run onto your property from elsewhere?
- Where does it run off your property?
- Does it already collect or pond too much somewhere?

1.5.1. Water is a valuable resource - know what happens to it on your property!

It's just as important to follow the path of water whether your house is already built or not. You'll have more options about lot layout if you're building from scratch, including locations for building and garden areas, paths, and driveways. But whether or

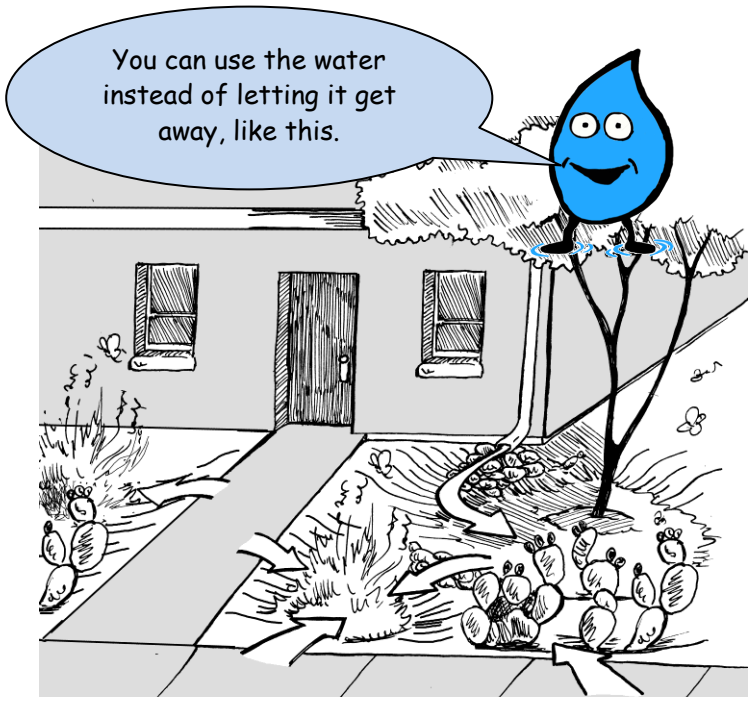
not your house is already built, understanding how water moves on your property and designing with it will help integrate your buildings and landscape better and make your home more beautiful - as well as using water more efficiently.

1.6. KEEP AS MUCH WATER ON YOUR PROPERTY AS YOU CAN

Here are some of the best ways to keep water on your land:

- *Maximize permeability and opportunities for infiltration*
- *Minimize impermeable surfaces*
- *Keep the water as close to where it falls as possible*
- *Provide physical containment wherever there's a good opportunity*

These ideas can inspire the design and layout of the outdoor spaces around your home. Most outdoor surfaces don't have to be completely waterproof. Sometimes a grassy or graveled surface will work fine, and even be more attractive. Flagstone, bricks, or other paving materials that come in individual pieces and leave room in between for water to soak in will do the job and still allow water to stay on-site. Even vehicle surfaces - driveways and parking - can allow water to infiltrate.



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Remember that plant roots help keep the soil porous and absorptive. Unless there's a good reason otherwise, plant cover is a good thing.

And even if there are places where you don't want plants to grow, don't cover the soil with waterproof plastic or similar coverings! Instead, use commonly available landscape fabrics that will keep weeds from growing but still let water soak in. Use them under gravel, for instance, rather than polyethylene or other kinds of waterproof plastic.

On most properties in Flagstaff, virtually all the rainfall and snowmelt could be retained to support plants and recharge our aquifer. The techniques on the following pages will help you use natural precipitation and water movement throughout your landscape and exterior design. Take advantage of free water from the sky - you'll be surprised at how beautiful the results can be.

1.7. PROTECT YOUR SOIL

It's hard to overstate how important it is to protect the surface of the soil. Bare soil does a bad job of allowing water to soak in. Unprotected soil becomes compacted in some places and washes away in others, while any water that does manage to soak in evaporates right away. Vegetation, especially native grass, plays a crucial role in getting water into the soil, keeping it there, and preventing runoff damage. Good soil-protecting vegetation, especially drought-tolerant grass, will:

- *Slow the movement of any water that collects on the ground*
- *Allow much more water to infiltrate into the soil*
- *Protect the soil surface from compaction*
- *Shade the soil and protect it from the wind, greatly reducing evaporation*
- *Make the soil more porous and let it hold more water, because of the effects of roots*

Even though plants use water, more water soaks into the ground with good plant cover than without it. Mulch like straw, bark, or gravel is much better than no ground cover but mulch by itself doesn't offer all the advantages for the soil that good native grass or ground cover plants do. The following photos show what native grass cover can look like in the Flagstaff area, compared with all-too-typical unprotected soil surfaces that erode rapidly and absorb almost no water.

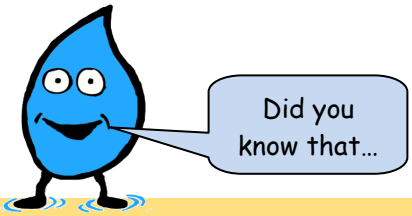
Bare and eroded soil.

Healthy grass cover that limits erosion and slows down the flow of water.

Precipitaion in Flagstaff is more than adequate to support healthy grass and wildflower cover, once it gets established (typically in two to three years). It does take time, attention, and usually some extra water at first to get native grass started on bare soil. Flagstaff has many local nurseries and landscape professionals, The Arboretum, and Master Gardeners who can provide expert advice, as well as the right seed. With proper plant selection and soil preparation, along with being mindful about care and timing, achieving a successful landscape is not only fun but is also very rewarding

During construction activities, or other times when soils are disturbed, it's especially important to provide extra protection for the soil to keep it from washing away. Several ways to protect disturbed soil are described later in the Erosion Control and Repair section.

4. WATER HARVESTING TECHNIQUES



Water harvesting just means keeping precipitation on your land so you can use it. An important part of water harvesting is catching water from hard surfaces, such as roofs, parking areas, or rocky places, and using it for landscape irrigation. Active rain water harvesting systems consist of a catchment area, a distribution system and a tank or cistern. These items will be discussed in detail later in this section.

In a passive rain water harvesting system, runoff is directed from the catchment area to a landscaped area, where water can be immediately used by the plants. Catchment areas include soil surfaces, roofs, roads and sidewalks. Passive water harvesting can use various methods, called "earthworks" to direct and hold the water. There are several advantages to this type of water harvesting:

- *Inexpensive*
- *Simple to build*
- *Low maintenance*
- *Turns your land into a sponge!*

Water harvesting helps:

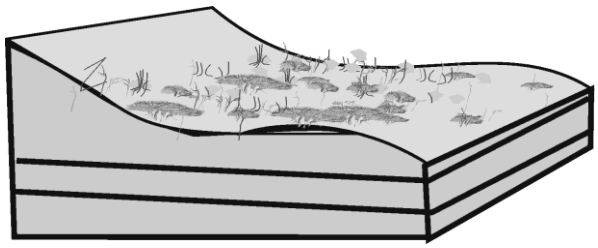
- Reduce landscape water bills
- Increase water availability for trees and other vegetation
- Reduce dependence on City water
- Keep valuable planting alive during water use restrictions
- Recharge aquifers
- Reduce erosion
- Keep plants healthier, since rainwater is low in salts and contains nitrogen.

Water harvesting is putting the principles from the last section – soil protection and keeping water on your property – into practice. In this section we'll look at several ways to do this, and show how you might combine techniques for a successful water-wise landscape.

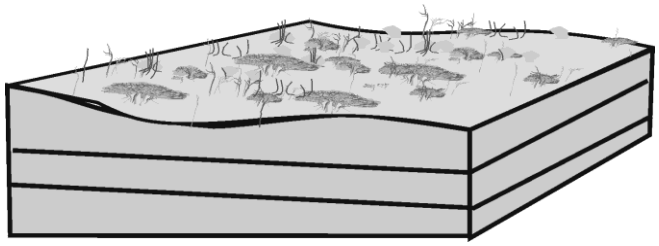
It's important that water drain away from foundations and walls, in fact it's required by building codes. The ground elevation from the foundation to at least 10 feet away should drop a minimum of 6 inches (5% slope). Do not locate an infiltration basin within 10 feet of a foundation, but swales can be used to convey water within this 10 foot area, provided they have at least a 2% slope (2.5 inches of drop for every 10 feet)

1.8. SWALES

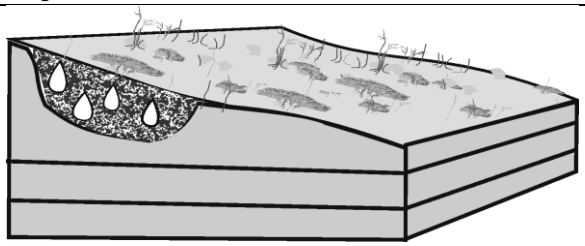
A swale is a level or gently sloping trench that collects, slows down, and diverts runoff water. Swales can vary greatly in width and treatment from small ridges in gardens to multiple long trenches graded across many acres of sloping land using heavy equipment. Swales are most often dug along slope contours, or perpendicular to the way water flows. Swales may be the single most versatile way to harvest water.



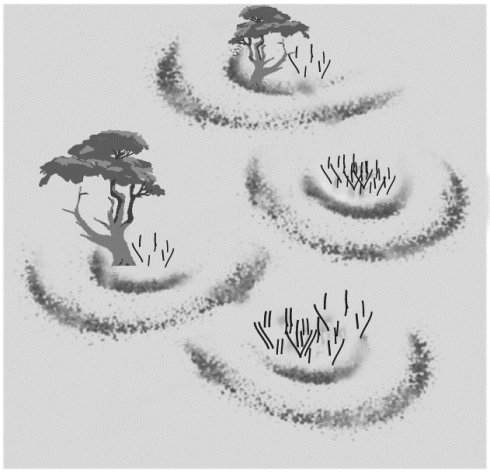
Generally a swale has a mounded ridge of soil – a berm - on the downslope side, that helps retain water that would otherwise run off. Sometimes the berm is strengthened with a stone border.



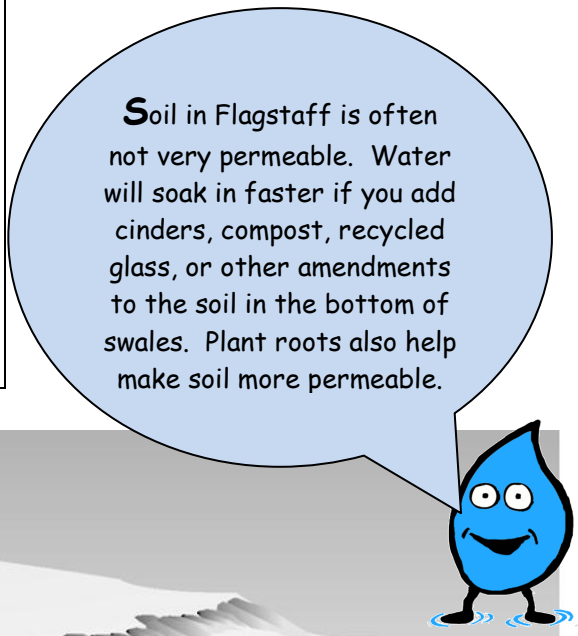
Some swales have no downslope berm at all. The gentler the slope, the better this works.



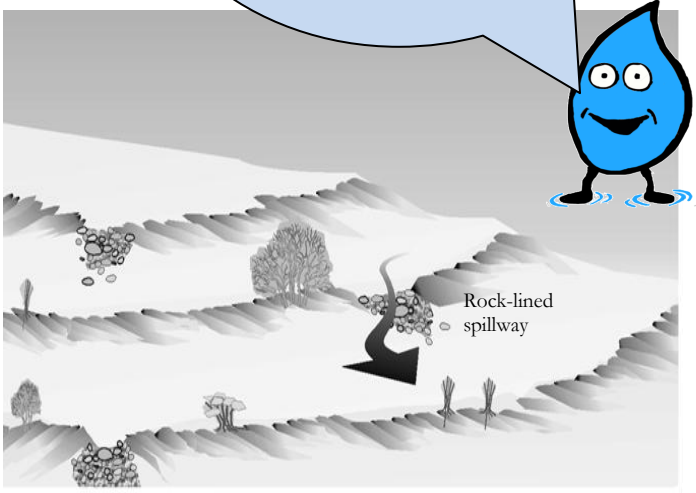
Some swales are hardly visible on the ground surface- they are really trenches filled with gravel or cinders so that water will soak in better.



"Eyebrow" or "Boomerang" swales concentrate water around a plant and work well with trees and on irregular slopes. They are semicircular in shape with the curved ends facing uphill and the ends generally level with one another.



In principle, if you have enough swales they shouldn't completely fill up with water unless there's an exceptional storm. But just to be sure, the top of contour swales should be level, so water will run over evenly instead of concentrating in one place. Better yet, provide a stone-armored spillway so any overflow won't erode your swale.



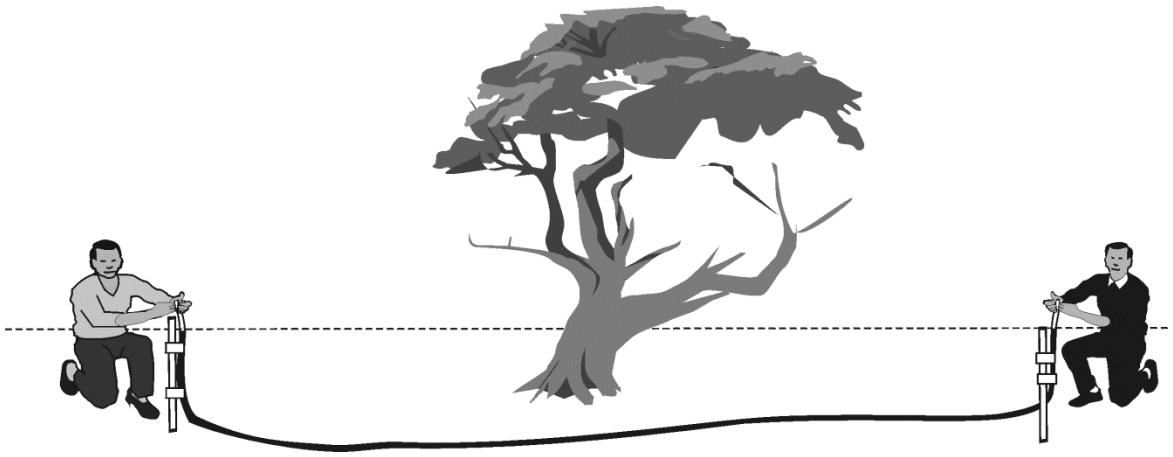
1.8.1. How to build swales

Swales should be spaced every 20 to 30 feet, starting as near the top of a hill as possible, to catch the runoff originating above each swale. If the swales are any more widely spaced, Flagstaff's intense thunderstorms are likely to produce more runoff than the swales can handle and the swales might wash out, especially if vegetation isn't well established or good spillways aren't provided.

Unless you intend a swale to gently convey water to another area (such as a detention basin), it should be built on contour. One good way to plan a swale before you start digging is to use an easily constructed water level. The materials required for a water level are two yardsticks, a length of clear plastic tubing (about fifteen feet long is good), and some strong tape to attach the tubing to the yardsticks. First, fill the tubing with water. Try to eliminate any bubbles. Clips are handy to temporarily close the tubing off to keep the water inside. Then attach the tubing to each yardstick, at two places near each end of the tubing. The tubing should run along most of the length of each yardstick. Next, two people take the yardsticks and one person places each yardstick vertically on the ground. When the clips (if they were used) are removed from the tubing, the water finds the same elevation at each end of the tubing.

One person stays at the place where the swale will start, while the other walks a few yards away and finds a place that looks close to the same level as the starting point. The people at either end of the tubing take turns calling out the height of their water lines (read from the yard sticks), and the person walking out across the slope keeps moving their yardstick slightly until the readings are the same. The levelled spot on the contour is marked with a rock or other handy object and then the next point on the future swale is surveyed.

Once the moving person reaches the end of the tubing, the first person (who stayed at the starting point) moves to the last surveyed level spot, and they repeat the procedure until the leading person gets to the end of the future swale. Then they move up or down slope to the start of the next swale.



If you encounter an obstacle like a tree while you are laying out a swale, you can route the swale around either side of the obstacle. The bottom of the swale doesn't have to be perfectly level (on contour), but the top of the berm should be as close to level as you can make it. The best tool for this is a line level (available cheaply, with instructions for use, from builder supply stores) laid out

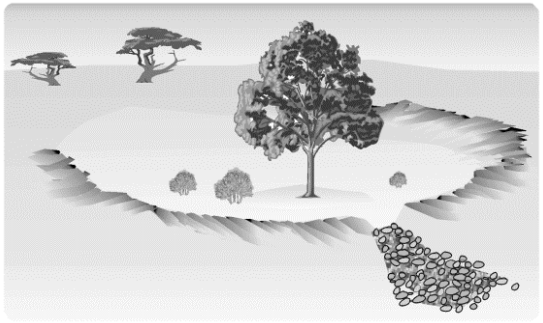
along sections of the nearly finished swale. Once the line level is laid out and verified level, the top of the berm can be visually inspected, or the height to the line level can be measured at several places with a ruler, to see that the berm is level. The idea is that if the swale ever filled up, it would start to overflow along much of its length rather than at one point, which would then erode. In addition, it's a good idea to build spillways protected with stones, brick, or something else that will keep them from eroding, as illustrated above.

1.9. TERRACES

Terraces are a similar idea to swales, and are what swales evolve into when slopes get steep enough (slopes steeper than about 3 horizontal feet to 1 vertical foot result in downslope swale sides that are too steep to stay in place without structural support like a retaining wall). Terraces have been used for millennia all over the world to slow runoff for plants, allowing it to soak in to the ground, and for keeping soil in place.

Local examples of terraces, one with sandstone and the other with rock, that flatten the existing slope, creating areas where water can slow down and pond.

1.10. INFILTRATION BASINS



Basins collect and infiltrate stormwater on gently-sloping or nearly flat land. Basins should be sited to take advantage of naturally occurring level spots or depressions. Basins, like swales, contain water and allow it to soak into the soil. Both basins and swales can support attractive planting and garden areas (known as rain gardens) and can be a focus of your landscape. Be sure to include a basin overflow that drains to a beneficial area for the times a larger storm will fill the basin. Locate trees and shrubs in raised areas within or near the basin edge and do not allow water to stand around plant trunks or st s

Residential rain garden fed by the roof downspouts. Note permeable pavement between rain garden and street.

One of the important benefits of basins, swales and any other water retention structures is that they are great places to get grass or other vegetation started, and the extra water they concentrate allows for more verdant plant growth with less irrigation.

1.11. MULCH

Mulch is a covering for theground surface that protects the soil from the erosive and evaporative effects of wind and sun. Mulch can be plant material, like straw, wood chips, and nutshells; or it can be gravel or non-living material like recycled glass, cinders, decorative rock, and recycled rubber. Mulch helps optimize water harvesting by holding water in the soil, and makes it much easier to get plants started and keep them alive. Mulch will:

With Mulch

Without Mulch

- *Reduce evaporation*

- *Increase infiltration by slowing runoff and giving it more time to soak in*
- *Reduce erosion from bare soil*
- *Make plant establishment easier and more successful*
- *Moderate soil temperature by reducing summer heat and winter cold*
- *Make it harder for weeds to sprout*
- *Supply nutrients and organic matter to soils*
- *Enhance habitat for earthworms and other important and beneficial soil-dwelling animals*

Shredded wood mulch is best. Research indicates that a 2 inch depth is near optimal. Less than that doesn't keep weeds down nor hold moisture as well. Three inches or more reduces the ability for precipitation and air exchange. Shredded wood can be either hardwood or coniferous (like cedar). The hardwood doesn't last as well. Bark chips doesn't work nearly as well and have a tendency to float during higher intensity rainfall events. Rock mulches aren't as good for the plants because of the heat they absorb and hold.

As a general rule of thumb, if the goal is to use mulch as a weed barrier that absorbs moisture and helps with erosion, use one of the following:

- *recycled tires, glass*
- *non-composted wood mulch at a thickness layer that not only generates some heat.*

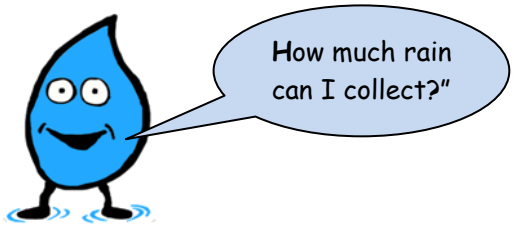
If the goal is to support vegetation, absorb moisture and address soil stabilization

- *composted wood mulch*
- *or a cover such as recycled glass or cinders that allows absorption.*

1.12. STORAGE TANKS AND CISTERNS

Storing and using rainwater for landscape plants is an alternative to using drinking water for irrigation and offers more control over when and how you can use the harvested water. Collecting rooftop rainwater for later use is described as "active" rainwater collection and generally it requires some degree of plumbing and perhaps pumping, in addition to the container or containers. Cisterns provide the most control and flexibility in saving harvested water, but generally also cost the most per gallon saved.

The quickest and easiest way to contain rain water is to put rain barrels under all your gutters or downspouts. You should realize, however, that a single 1-inch rain (typical for a good summer thunderstorm) on a 1500-square-foot roof will yield almost a thousand gallons of water – that's more than 18 rain barrels!



Of course, it can also go a long time without raining in Flagstaff. If you're serious about saving runoff water in containers, you'll want to invest in a bigger tank or multiple tanks. This section will describe the basic components of active RWH systems and how to get you started with your own system. Before you set up an active rainwater catchment system, the following questions should be considered:

- What will the water be used for?
- Will you want to expand the system later?
- How much rain can be collected?
- Where will the tank overflow go?
- Where can the containers be located? Above or below ground?
- Can the containers serve several purposes where they are located such as shading a garden, providing a windbreak or as the edge of a structure?
- Do you want to hide the containers for aesthetic purposes or neighborhood restrictions?
- How will the water get from the roof to the container and to the end use area?
- Will the system be gravity fed, or will it need a pump?

To calculate collection potential, multiply:

square footage of collection area by the rainfall (in inches) by 0.623 (conversion to gallons) by an efficiency factor for the collection type.

The efficiency factor is approximately 90% for most roof types

Example:

Roof area = 1,000 sq ft

Flagstaff's annual Rainfall = 22 inches

Roof area x annual rainfall = 1, 000 sq ft x 22 inches x 0.623 x 0.90 = 8,140 gallons/year

Rules of thumb:

1000 square feet of roof = 623 gallons from a 1" rain

One foot of water elevation = 0.43 psi

2.31 feet in elevation = 1 psi,, no matter the size of the storage tank

Water weighs 8.34 pounds per gallon

There are 7.48 gallons in one cubic foot of water

1.12.1. Collection Area

Roof surfaces provide the most common opportunity for rainwater capture. The smoother, more impermeable the collection surface, the less debris accumulates (keeping the stored water cleaner) and the greater the quantity of water collected. Powder coated steel is one of the best surfaces to consider since its very smooth surface sheds water easily during rain events. Roofs using asphalt shingles, one of the most common roofing products, produce grit granules that should be filtered out before the water gets to the cistern (see Pretreatment advice below).

1.12.2. Conveyance System

The conveyance system directs the water from the collection area to the storage container and is typically comprised of gutters, downspouts and/or piping. The most common materials for gutters and downspouts are half-round PVC, vinyl, and seamless aluminum. The downspout routes water from the gutters downward through the downspout pipe. Whenever possible, fit the downspout

pipe snugly to the side of the house. If this is not possible then simply make sure that the pipe is stable and is firmly connected to the inlet of the tank using rubber grummets.

1.12.3. Pretreatment

To prevent clogging of the conveyance system and sediment build- up in the storage tank, basic filtration is needed to remove debris that will wash off the catchment area. The type and number of filtering components on a system depend on the amount of roof debris.

Gutter and downspout leaf screens are the first defense in keeping debris out of the cistern. These screens are usually made of 1/4 inch metal or plastic mesh frames that fit along the length of the gutter. Leaf screens must be regularly cleaned to be effective. If not regularly maintained, leaf screens can become clogged and prevent rainwater from the flowing into the tank.

Examples of rain gutter leaf screens

Another type of screen is the downspout filter. It is typically made of PVC and fitted with an aluminum or stainless steel screen. This type of filter offers the advantage of easy accessibility for cleaning. The funnel is cut into the downspout pipe at the same height or slightly higher than the highest water level in the storage tank. Care must be taken to have the filter high enough to prevent contamination from dogs, but low enough not to discourage the owner/operator from maintaining and cleaning the filter on a regular basis.

Leaf Eater® Downspout Filter

Strainer baskets are a drop in screen that fits into the inlet of the cistern. This provides further protection from debris or small animals and should be located above the maximum water line in the cistern.

Strainer baskets. Pictures from www.therainwell.com.

While screens remove the larger debris, the initial roof runoff (often called the "First flush") from the catchment area can contain smaller contaminants such as dust, pollen, and bird and rodent droppings. The first flush diverter (sometimes referred to as "roof washers") routes the first flush away from the cistern and, ideally, to a landscaped area. The simplest first-flush diverter can be constructed with a PVC standpipe. The standpipe fills with water first during a rainfall event then the balance of water is routed to the tank. The standpipe is drained continuously via a pinhole or by leaving a screw-on end cap slightly open. In any case, cleaning of the standpipe is accomplished by removing the PVC cover and removing collected debris after each rainfall event. The volume of the first flush is variable and dependent on a number of factors including the type of catchment surface, time between rain events, presence of trees, etc. But a general rule of thumb is 3-10 gallons per 1000 sq sf of catchment area.

There are also a number of commercial first flush diverters available.

Ultra Downspout Diverter
from Clean Rain ™

First Flush Diverter from
RainHarvesting™

1.12.4. Water Storage (Tank or Cistern)

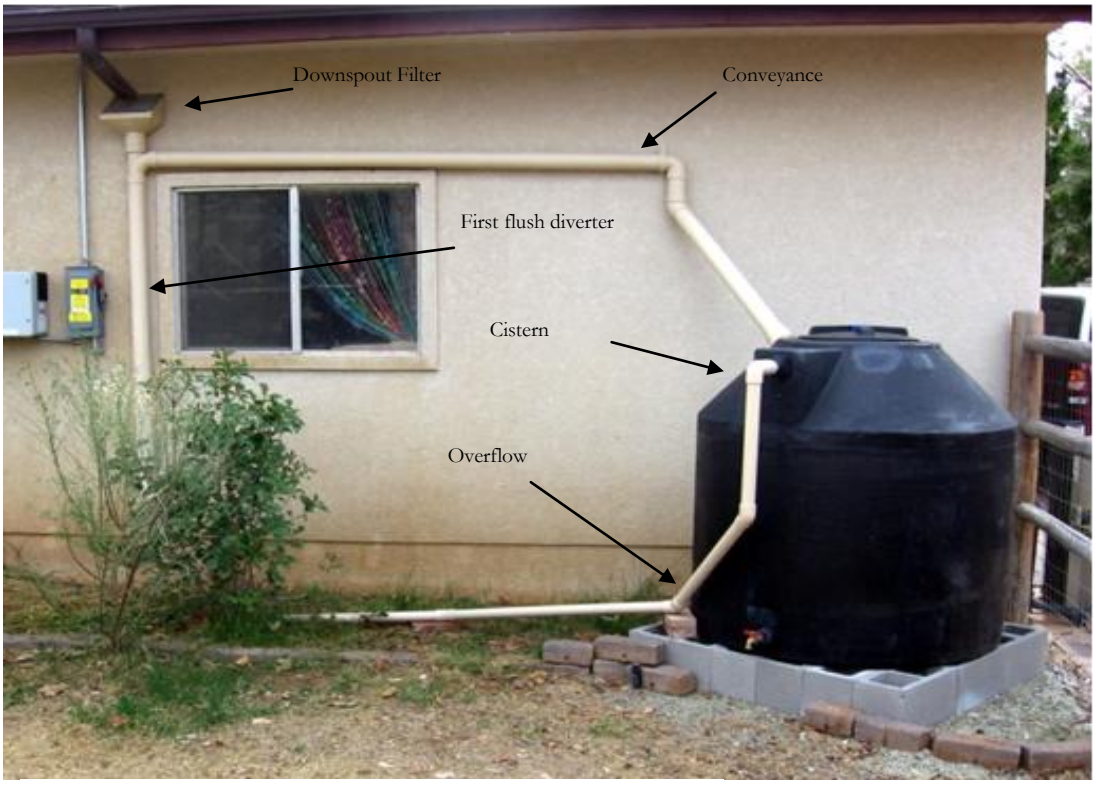
The tank, or cistern, is the most important and expensive component of an active rainwater harvesting system. In many cases it is permanent and therefore its placement should be carefully thought out. A storage tank can be as simple as a salvaged 55-gallon drum (be sure it's clean!) or garbage can; or as sophisticated as a large site-built underground cistern collecting all your roof runoff. Cisterns are made from a variety of materials including fiberglass, polypropylene, wood, metal and concrete and can be comprised of a single container or multiple containers. Above-ground tanks are often plastic or metal while underground tanks may be concrete or plastic.

The size of the cistern is dictated by several factors including the rainwater supply,frequency, catchment area, demand, aesthetics and budget. In Flagstaff most of the annual rain comes during the monsoon season; short periods of intense rainfall, typically during the months of July through September. Large volumes of runoff are generated during these rain events, so obviously a larger cistern will allow more runoff to be harvested and used during the period between the end of the monsoons and the end of the growing season when rain is less frequent. Historically the months of April, May, and June are the driest in Flagstaff and a larger cistern filled with snow melt will last longer during this time before using drinking water for irrigation. A rough rule of thumb is to provide 1 gallon of storage for each square foot of roof or collection area.

Above ground cisterns need not be an eyesore. Plastic or metal tanks can be wrapped with wood or screened and many manufactures offer plastic tanks in natural colors and shapes that allow the cistern to be integrated into the landscaping, incorporated into fencing, or many other uses.

Cistern hidden with wood and a Bushman® Cistern that can fit along a wall or be incorporated into a fence. Pictures courtesy of Eden on Earth

Regardless of the type of storage tank used, they should be opaque or otherwise protected from direct sunlight to inhibit algae growth and screened to discourage mosquito breeding and reproduction. Tanks should be accessible for cleaning, inspection, and maintenance.



Typical gravity cistern system. Photo courtesy of Carl Ramsey

Some items that should be kept in mind when planning a cistern for your rainwater harvesting system:

- *Cover tank openings to prevent evaporation and keep light out. Light promotes algae growth. Dark colored tanks are preferable to light color tanks as they do a better job of keeping light out*
- *Above ground tanks should be UV resistant to prevent damage from the sun. Tanks can be painted with rubberized paint (no tank prep or primer needed for poly tanks) to provide sun protection, help prevent light from entering and/or make them blend with surroundings, or be fun and interesting*
- *On multiple tank systems, install shutoff valves between tanks for easy maintenance*
- *Identify water supply outlets as a "non-potable"*
- *Water reaches its own level, so interconnected multiple tank systems will only fill to the highest point on the lowest tank*
- *Be sure tanks are level*
- *Tanks located in windy areas should be tied down or store a reserve of water to as ballast*
- *Large tanks should be situated 5-10 feet from foundations and be placed on a surface such as a cement pad, pea gravel base, or compacted earth*
- *Tanks can be raised to increase water pressure and to easily access the water outlet*
- *Mosquito and animal-proof tank access points. If this is done, mosquitoes should not be a problem. However, if they become a problem, a microbial insecticide specific to mosquito larvae containing Bacillus thuringiensis israelensis (Bti) can be used and is easy to find in gardening catalogues and in garden departments, often called "Mosquito Dunks".*
- *Direct the overflow to a useful area, away from the tank foundation, buildings, and toward plants*
- *Partially bury the cistern, and/or build a short retaining wall around the cistern and backfill with soil, to help insulate the cistern and prevent freezing. Larger cisterns may develop an ice layer up to 8 inches thick on the surface, but will not freeze solid and will not cause damage to the cistern.*
- *Weatherize water pipes and outlets to protect from freezing and UV degradation*
- *Any tanks used for underground storage must be rated for this use*
- *If possible, use a floating pickup to draw water from the middle of the tank since the bottom may have sediment deposits and the top floating debris*
- *A tank inlet component that helps calm the entering water will help prevent stirring up the sediment layer*

Water from rainwater cisterns is not safe to drink unless it's been treated! Treatment for domestic use is certainly possible, but is beyond the scope of this manual.

1.12.5. Distribution System

Most distribution systems are gravity fed or operated using pumps to convey harvested rainwater from the storage tank to its final destination. Typical outdoor systems use gravity to feed hoses via a tap and spigot. Methods of irrigation such as basin flooding or low pressure drip systems can be used for gravity fed systems.

1.12.5.1. *Gravity*

A gravity drip irrigation distribution system is easy to install and generally consists of a timer, tubing or hose, and emitters. It is important that all components be designed for low pressure systems. Standard drip systems that can be purchased in hardware stores are designed to operate at 15-30 psi (pounds per square inch) and will not work with most cisterns or rain barrels.

This gravity fed irrigation system feeds directly into a square foot vegetable garden. Easy to build and easy to care for!

A low pressure system operates in the range of 2-10 psi (equivalent to 4.6 feet of water to 23 feet of water). Timers should be low or zero pressure and can commonly be found on-line. By contrast, many standard timers require at least 10 psi to operate. Similarly, common garden hose valves have interior diameters that are constricted, resulting in a pressure increase and reduced flow volume. Full port ball valves and spigots have much larger diameters for the same valve size with little or no change in flow. These can be found at most plumbing supply stores. Depending on the quality of the harvested water in the cistern, a Y-type filter can be installed to prevent the distribution system form clogging.

The tubing is the backbone of the distribution system. As a general rule, the larger the diameter of the tubing leading from the cistern to the plants (the mainline), the less pressure is needed to distribute the water. And the longer the mainline tubing, the more pressure is required; therefore, locating the cistern as close as possible to the area to be irrigated is preferable and will require less pressure to operate. Less pressure means a lower water level in the cistern. Most tubing is made of polyethylene and typically comes in ¼", ½", ¾", and 1" diameters. The ¼" tubing can be connected to the mainline tubing with simple fittings and run to the plant to be irrigated. This tubing can be fitted with an emitter, or left open depending on the pressure in the system. The mainline and branch tubing can all be covered with mulch after it is installed.

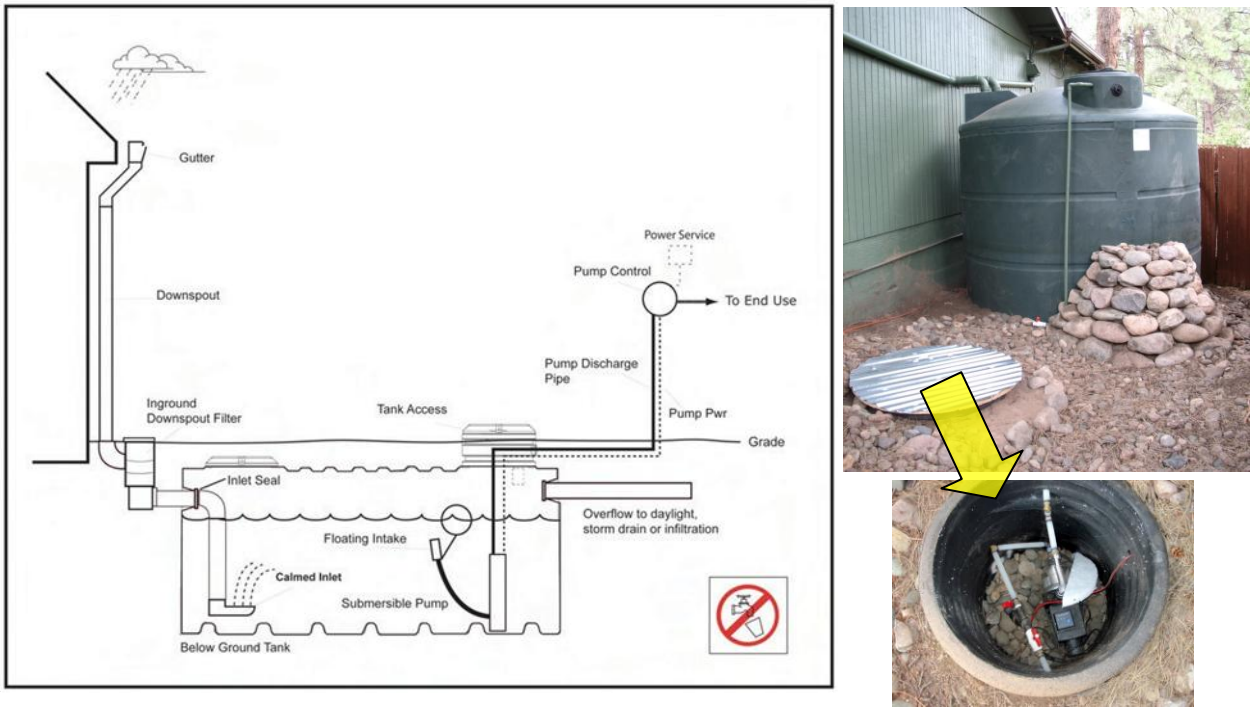
Depending on the water level in the cistern along with the length and diameter of the tubing pressure equalization may be needed. Friction in the tubing results in pressure losses that slow the flow of the water and if the pressure is too low, the tubing and/or emitters at the end of the system may not flow at all. For longer systems it may be necessary to install low flow emitters (higher pressure required for flow) closer to the cistern and open micro tubing (lower pressure required for flow) towards the end. Emitters act as small throttles, reducing and regulating the amount of water discharged, assuring that a uniform rate of flow is emitted. Typical flow rates from emitters range from 1/2 gallons per hour to 2 gallons per hour. Using lower flow rates means you can install more emitters for a given pressure.

1.12.5.2. ***Pumped System***

For underground cisterns, flat, or large sites, a water pump will likely be needed. On-demand pumps eliminate the need for a pressure tank and are designed to activate in response to a demand. These pumps combine a pump, motor, controller, check valve, and pressure switch with pressure tank function all in one unit. They are self-priming and are built with a check valve incorporated into the suction port. In addition, some on-demand pumps are specifically designed to be used in rainwater systems.

Intake filters are designed to exclude debris from the pump intake. These filters assist in preventing clogs, improving reliability, and increasing pump life. The floating suction filter attached to the intake on the pump allows the pump to draw water from the storage tank 6 to 16 inches below the water surface. Water at this level is cleaner, fresher and relatively more oxygenated than water closer to the bottom of the tank. These devices have some filtration, usually between 100 and 200 microns.

Many systems also have a back-up municipal water supply line feeding into them (i.e., "make-up" line) to provide a means of topping up the cistern with potable water when rainwater levels in the cistern fall below a specified level. A backflow preventer is required on "make-up lines" to prevent harvested rainwater from backing up into potable water supply lines. An alternative design switches fixtures connected to the cistern to municipal supply until additional rain or snowmelt fills the tank.



Examples of cisterns, one a below groud (buried) system and the other an above ground system with a pump. (Diagram from Georgia Rainwater Harvesting Guidelines by The Georgia Department of Community Affairs, by Eddie Vangiesen.)

1.13. PERMEABLE PAVING

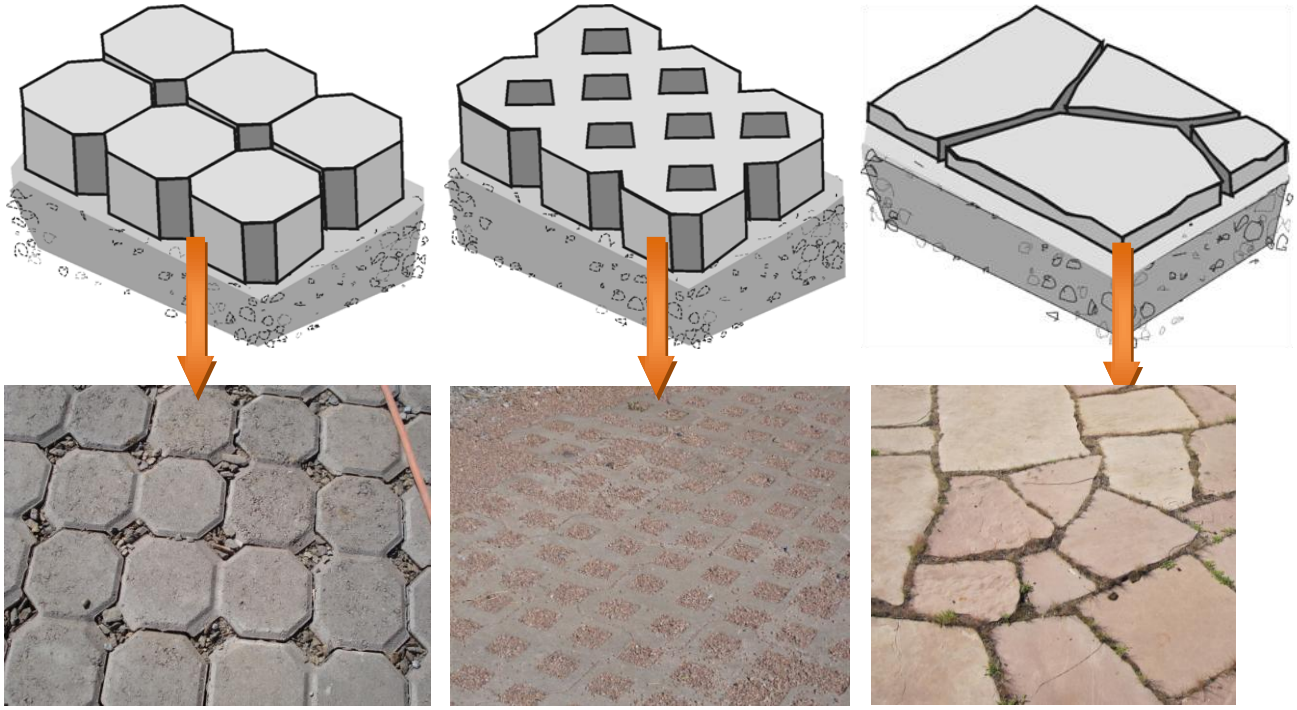
Gravel can be a suitable paving surface for driveways and parking areas that allows water to soak into the soil below. A well-constructed gravel driveway can remain relatively smooth with minimal maintenance because it is lightly used by slow moving vehicles. Crushed stone aggregate such as 3/4" to 1-1/2" granite is more suitable than rounded stones like pea gravel, because the angles of the crushed stone interlock to form a matrix that stays in place and supports weight better.

While gravel is better than asphalt or concrete for letting water soak in, the gravel itself and the soil underneath the gravel often tends to suffer compaction over time, and ruts may develop in the gravel surface. There are specialized structural products on the market that help support the weight of vehicles while containing the gravel, preserving its ability to let water soak in and prolonging the life of a gravel drive or parking area and.

For example, a plastic honeycomb matrix can be buried underneath a gravel layer to distribute the weight of traffic while keeping the gravel in place (see below).

Plastic reinforced gavel parking. Museum of Northern Arizona Collections Building Parking (left) and Kingdom Hall of Jehovahs Witnesses parking (right)

Another alternative is porous interlocking concrete pavers (PICP), which can make an attractive driveway that is still permeable due to the voids between the pavers. A pavement of brick or paving block on sand, or turf-block, can make the driveway more integrated with your landscape or garden, rather than a hard and intrusive extension of the street penetrating deep into the garden space.



PICP Paving Block Flagstone

Engineers, landscape professionals, and the Flagstaff Stormwater Management Section can provide more information on this and other water-friendly paving surfaces best for your situation.

1.14. CHECK DAMS

Check dams are a great way to capture sediment in drainage ditches or channels to reduce erosion. At the same time, they capture water and make it available for plants. The sand and sediment

caught upstream of a check dam is usually very permeable and it's easy for water to soak in. The additional level area in the channel increases the area for infiltration, and water stored underground is less vulnerable to evaporation. This all means that check dams can be great places to get trees, shrubs, grass, and other vegetation to grow. The vegetation, in turn, helps further encourage infiltration, slow runoff water, and structurally reinforce and protect the check dam.

Runoff without checkdams

Runoff with checkdams

1.15. VEGETATION

In Section I on site design we emphasized how important it is to keep the soil protected and let plants help keep water from running off or evaporating. Even plants we're used to thinking of as "weeds" are generally better than bare soil. It's a good goal to try not to have any bare, unvegetated soil on your property. It is important to stabilize the disturebed areas to "out compete" invasive weeds.

Unless you have other plans for an area, consider native grass and wildflower cover. That's mostly what would be growing here naturally, and it offers all the advantages we've mentioned for soil protection and water infiltration. Native grass (and there are many varieties) can grow quite thick and become beautiful vegetation all by itself. Be aware, though, that it's not supposed to be green all the time! No matter how much water you put on native grass, it won't look like a turfgrass lawn. It has a beauty, and diversity, all its own.

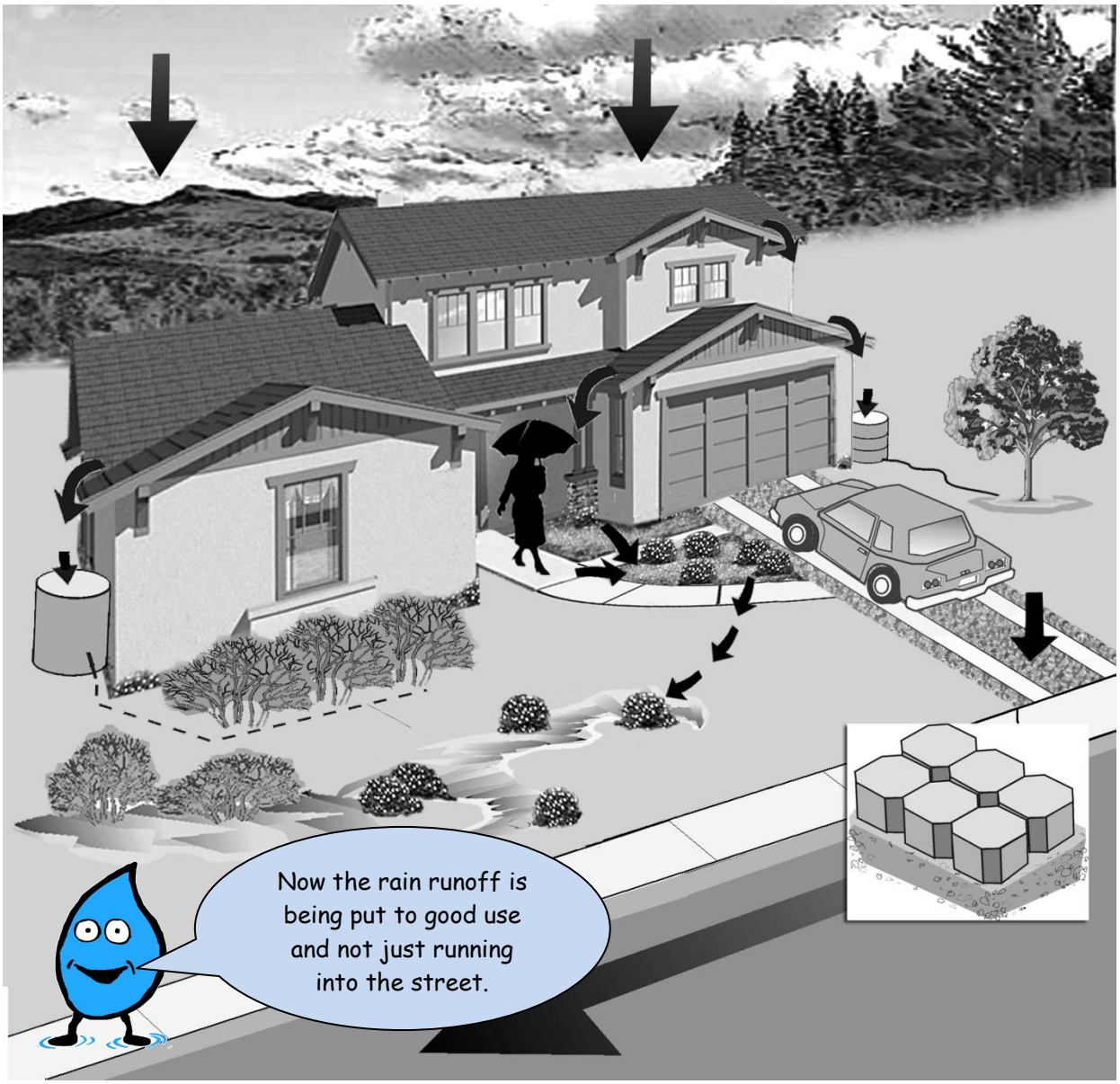
Native grass may seem tricky to get started, but it's mostly just a matter of timing and making sure new seedlings stay moist when they're small and vulnerable. You can do this with mulch and/or irrigation, as well as planting to take advantage of natural summer precipitation patterns. Most dryland seed mixes contain seeds of both "cool season" and "warm season" grass species. The cool season grasses (like Indian ricegrass and streambank wheatgrass) germinate in the early spring as the snow melts, and warm season grasses (like galleta, which every good dryland mix should have, sideoats or blue grama, little bluestem, alkali sacaton, and sand dropseed) germinate and grow best in warm weather following summer thunderstorms. The cool season or spring growers have the benefit of low evaporation rates, but the summer or warm season growers require repeated rain events (or irrigation) to survive past the seedling stage. Once established, these grass species (which are all perennial) will survive dry times and will green up again during moister periods.

There are also broadleaf plants - wildflowers - that bind the soil well and are desirable for their beauty, but they are generally not included in dryland seed mixes because of their expense. Seeds of these species are more often purchased separately. The standouts among them are the annual purple aster, chocolate flower (a perennial), pepper grass, evening primrose (several species), *Ratibida* (one of a couple plants called "coneflower"), buckwheat, sunflower, penstemons, and "perky Sue". Buffalo gourd is a large and dramatic native plant that may be appealing. It provides soil cover as well as adding some organic matter to the soil when its huge taproot decomposes after the plant dies.

The places where water concentrates from roofs or hard surfaces and soaks in can be considerably wetter than surrounding areas that receive straight precipitation. These are the places to put more water-loving plants, while places with no additional water will still support native grasses, shrubs, and wildflowers. By organizing plantings to work with your yards water flow, you can have more verdant spots and a very attractive overall landscape with little additional water needs other than what falls from the sky. Swales and infiltration basins are the perfect places to get plants started and support relatively water-loving ones.

1.16. PUTTING IT ALL TOGETHER

This example of a hypothetical home and yard illustrates many of the ideas from the previous pages. Techniques can be combined and put to use in ways that reinforce their effectiveness and contribute to an attractive landscape that retains and uses most of the precipitation it receives. Remember, water is valuable. Don't let it get away!



5. EROSION CONTROL AND REPAIR

Keeping water close to where it falls and letting it soak in to support natural vegetation will almost always keep erosion from getting started in the first place. Often, however, native plant cover has been disrupted and unprotected soil is rapidly eroding. The key to preventing and repairing erosion, just like water harvesting, is to protect the land surface and slow down the water so it can soak in. Appropriate plant cover is one of the most effective ways to do this.

To prevent erosion we have to stop it while it's still easily manageable, on our own back yards and construction sites. Can you recognize an erosion problem before it gets out of hand? Here is an example:

Unprotected soil is easily washed away . The loss of topsoil will make it harder to establish vegetation, and in this case also impacts the neighborhood.

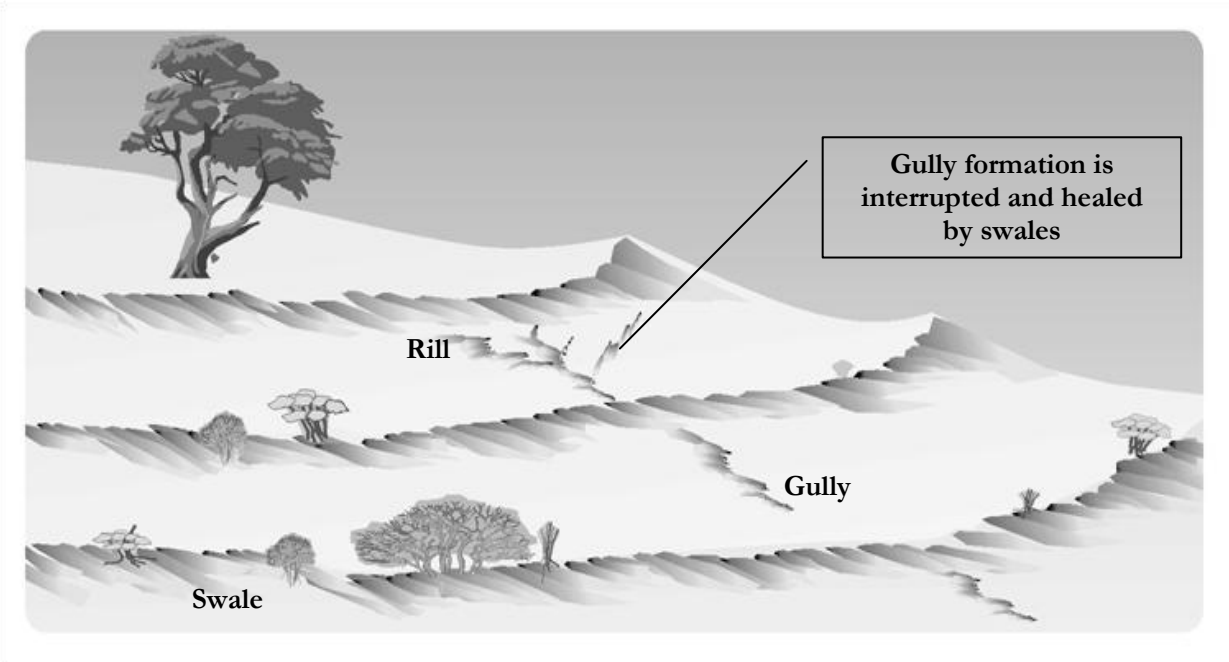
Bare soil is always erosion waiting to happen. Water will run rapidly off unprotected soil, and soon concentrates to form little channels called rills that join to form gullies. These are bleeding wounds that need attention!

Always start at the top, if you can. The higher up on your property or on any watershed you can work to prevent or repair erosion, the easier and more effective it will be. A little digging or revegetation will work wonders before runoff has a chance to concentrate and build up volume and momentum.

1.17. SWALES

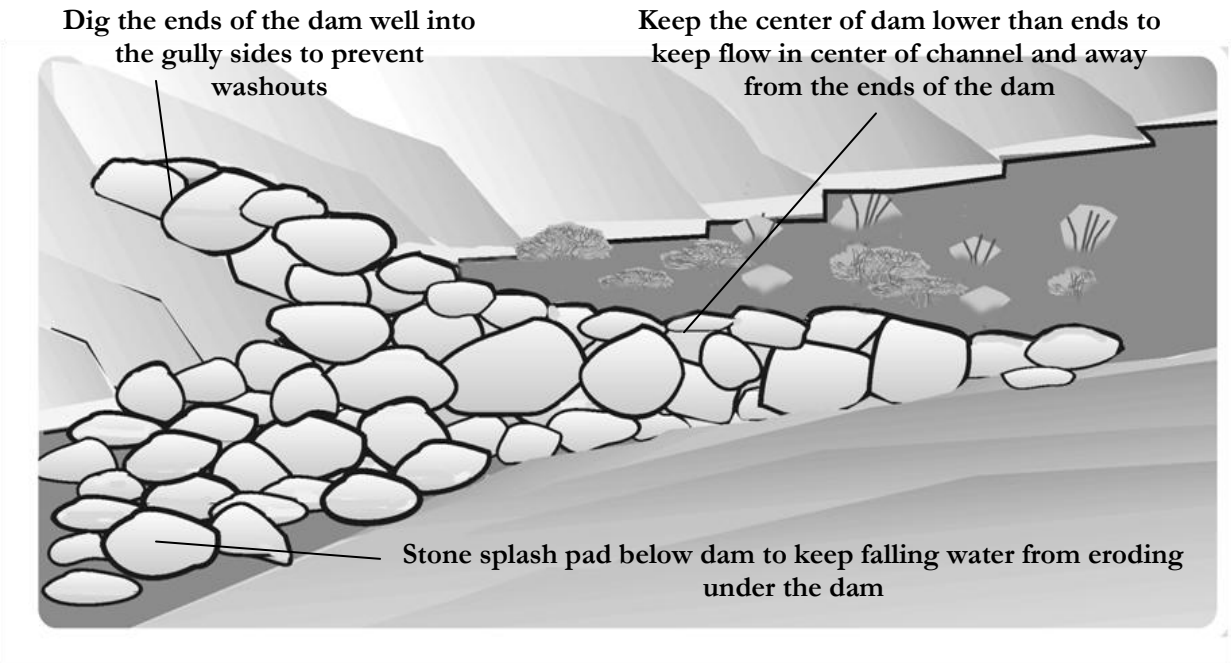
The same simple and effective swales that work for water harvesting because they slow the water down, let it soak in, and provide great places to start plants, also prevent the formation of rills and

gullies. Containing runoff with swales at the top of a slope will reduce or eliminate the need for bigger, more labor- and material-intensive structures further downstream.



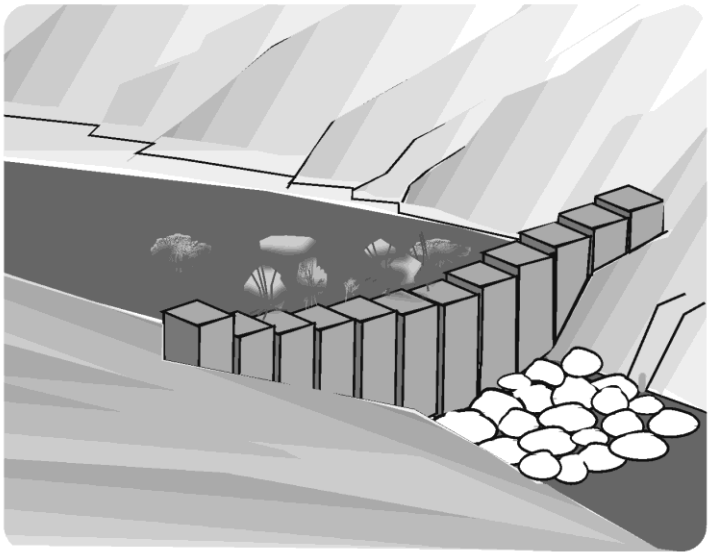
1.18. CHECK DAMS

Sometimes you can't start at the top of the watershed. Maybe you have gullies running onto your property from somewhere else and can't do anything about the land upstream. If you need to work in a gully or channel of any size, the main tool you have is the check dam - a low dam that is designed primarily to slow water flow and collect sediment. The sediment is a great way to store water and support a plant community that further protects and stabilizes the soil above the check dam. Small gullies, less than a foot or two deep and less than four or five feet across, can often be repaired with a series of simple check dams made of nearby stone, piled by hand into the channel. There are a few important points to remember, though, as illustrated below.



Sometimes one or two check dams will stabilize an eroding gully, but often it will take several to do the job. You want it to be as nearly level from the bottom (or "toe") of one dam to the crest of the one below it as possible.

You can also make check dams out of cut railroad ties, set vertically into the bottom of the gully deeply enough that they won't wash out (say a foot or more). Railroad ties laid horizontally are easily washed out by the force of flooding water, and usually don't work in the long run.



If you prefer not to use railroad ties there are alternatives available, including posts the size of railroad ties made of recycled plastic, and naturally rot-resistant wood like juniper.

It's not a good idea to make permanent check dams out of straw bales, brush, or ordinary lumber because when these materials rot or give way, the gully will rapidly wash away all the sediment caught above them, undoing all your hard work in a single storm. Perishable materials should only be used for temporary erosion protection (such as on construction sites), or where you are sure that plants you can grow on captured sediment will be dense and strong enough to keep all the sediment in place by themselves. Generally in the Flagstaff area there is not enough water available for this.

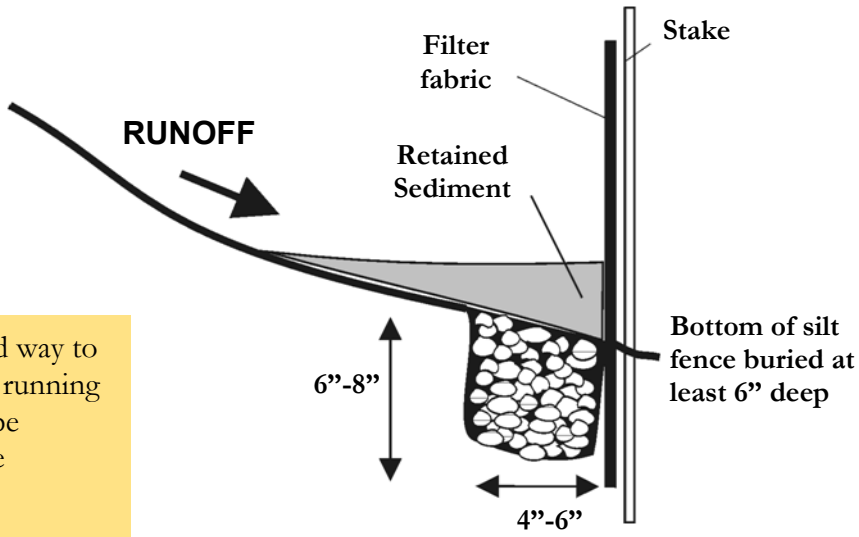
In general, check dams for drainage ditches more than a foot or two deep, or four or five feet across, will need to be stronger than just hand-stacked stone. They may need the reinforcing wire baskets called gabions, or other engineering design. It's a good idea to consult with an erosion control or engineering professional in these situations.

1.19. TEMPORARY EROSION AND RUNOFF CONTROL

Soil is most vulnerable when it's recently disturbed and has no protective vegetation at all - and a construction site is a great place to find soil like this. Soil needs extra protection during construction activities or similar disturbances, and there are more and more legal requirements to do this.

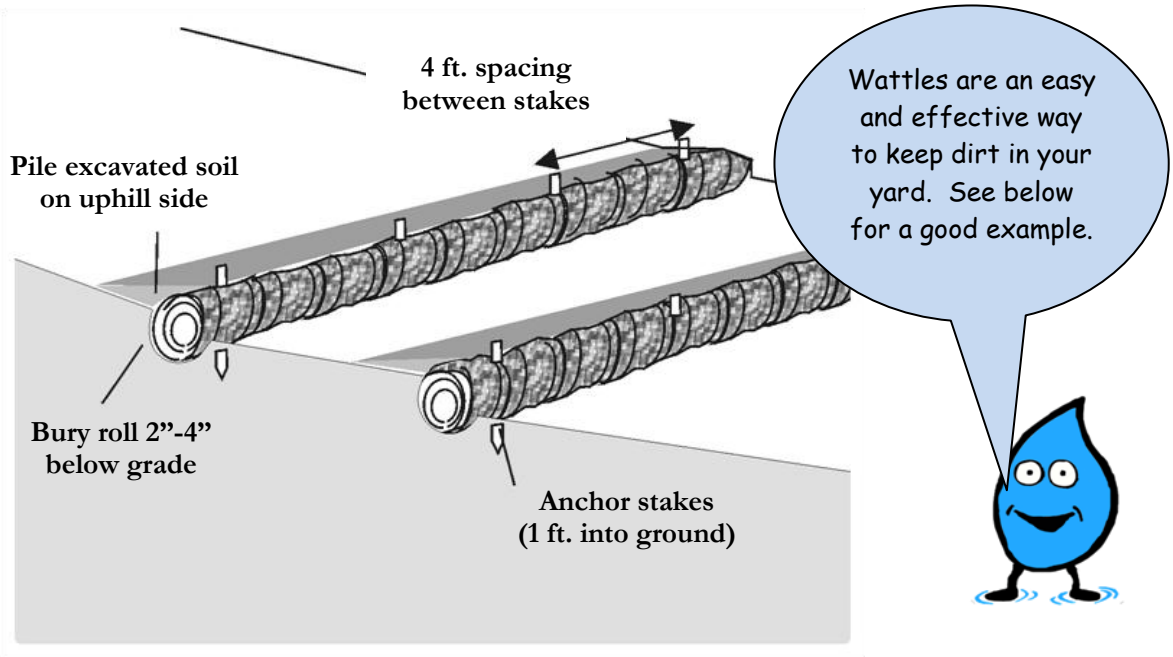
Once again, the key is to follow the path water will take across and off your construction site, to make sure it can't just run off unimpeded carrying soil with it. There are many ways to keep water under control and keep soil from leaving a building site. Here are some of the most common techniques.

Silt fencing is one of the quickest, cheapest, and easiest ways to retain sediment on a construction site. This is the black fabric that you've seen on highway projects, standing up about a foot high. It lets water filter through but slows it down so silt drops out. Perhaps the most important thing to remember about silt fencing is that it won't do any good unless it extends down firmly into the soil. Don't let the water just run underneath it!



Silt fencing is a good way to keep sediment from running off the site. But to be effective, it has to be installed correctly.

Fiber rolls, also called sediment rolls or wattles, are biodegradable fibers rolled inside open netting. They work like straw bales to allow water to filter through while keeping sediment behind and slowing runoff. They may be more convenient than straw bales where longer lengths are needed. Wattles are installed by digging a shallow trench and setting the wattle in so that the bottom third is in the trench. Stakes are then driven through the wattle to hold it in place (see below).



There were many methods and techniques presented in this Guide that hopefully gave you the incentive and knowledge to use the runoff from your property to your advantage, rather than to dispose of it as quickly as possible. The City of Flagstaff, Stormwater Section personnel are also available to offer advice on drainage and/or erosion issues you may have on your property. In addition, check out the resources below.

6. RESOURCES

Many of the following publications were useful in the preparation of this handbook and are recommended reading for more in-depth information about water harvesting.

- *Harvesting Rainwater for Landscape Use.* Patricia H. Waterfall, Cooperative Extension, University of Arizona, 2nd Ed., 2004.
- *Introduction to Permaculture*, Bill Mollison. Tagari Publications, 1988.
- *Natural by Design: Beauty and Balance in Southwest Gardens.* Judith Phillips. Museum of New Mexico Press. 1995.
- *Rainwater Harvesting: Supply from the Sky.* City of Albuquerque. 2001.
- *Start at the Source: Residential Site Planning & Design Guidance Manual for Stormwater Quality Protection.* Bay Area Stormwater Management Agencies Assoc. January 1997.
- *Sustainable Landscape Construction: A Guide to Green Building Outdoors.* J. William Thompson *and Kim Sorvig.* Island Press, 2nd Ed, 2007
- *Texas Guide to Rainwater Harvesting.* Wendy Price Todd and Gail Vittori. Texas Water Development Board, Second Edition 1997.
- *Forgotten Rain: Rediscovering Rainwater Harvesting.* Heather Kinkade-Levario. Granite Canyon Publications, 2004
- *City of Tucson Water Harvesting Guidance Manual.* Ann Audrey Phillips, City of Tucson, 2005
- *Rainwater Harvesting for Drylands and Beyond, Volume 1: Guiding Principles to Welcome Rain Into Your Life and Landscape. Brad* Lancaster. Rainsource Press. 2006
- *Rainwater Harvesting for Drylands and Beyond, Volume 2: Water-Harvesting Earthworks. Brad Lancaster.* Rainsource Press. 2007
- *"Water Harvesting Traditions in the Desert Southwest," Joel Glanzberg. Permaculture Drylands Journal, #30, pp. 25-27.* Permaculture Institute. Summer 1998.
- *A Guide: Rain Barrel Water Harvesting.* Terry Sprouse, Amy McCoy, and Joaquin Murrieta. . University of Arizona, Water Resources Research Center, 2005

The following web sites also have interesting information relating to water harvesting.

- *rainwaterharvesting.tamu.edu/*. AgriLIFE Extension Service, Texas A&M System
- *www.harvestingrainwater.com/*. A very comprehensive site by Brad Lancaster with extensive information on water harvesting

- *www.harvesth2o.com*. dedicated to the advancement of sustainable water management practices for individuals, families, communities, and businesses.
- *http://cms3.tucsonaz.gov/water/harvesting*. City of Tucson site with good guidance on harvesting rainwater.

The following local resources are also available to help in water harvesting.

www.nativeplantandseed.com. A local nursery and landscaping company that supplies cisterns and is a good resource for native and drought tolerant plants.

www.warnercompanies.com. A local nursery and landscaping company that supplies cisterns and rain barrels, and is a good resource for plants.

www.showtimedirtworks.com. Local company that provides active rain water collection systems xeriscape landscaping.

coconinomgassociation.blogspot.com. Website for the Coconino Master Gardener Association. Contains information about plants, training events, and many other resources.

www.thearb.org. The Arboretum at Flagstaff has many native plant demonstration gardens and often offer workshops and other education opportunites.